Handbook of

RECOMMENDED ENVIRONMENTAL CONDITIONS AND HANDLING PROCEDURES FOR MAGNETIC TAPE

DISCUSSION DRAFT.

JULY 1972

Written by Data Archives Branch
National Archives & Records Service

Approved For Release 2002/04/03 : CIA-RDP75-00163R000100050006-7

1. Background

Federal Records Centers are accessioning magnetic tapes in ever larger numbers and the volume is increasing continuously. Until recently, technical information was not available on how magnetic tape reacted to its physical environment, and the transportation, storage and maintenance problems attendant therein. This information has recently become available and these recommendations are based on it.

Agencies which are major users of magnetic tapes have independently developed internal policies and procedures for tape storage, maintenance, and protection. A number of agencies and government contractors have separately contracted for research and development in various aspects of magnetic tape storage, maintenance, and transportation. These activities have not been coordinated; information acquired by one agency is not necessarily made known to others, and the general scarcity of standards has resulted in widely varying methods of storage, maintenance, and transportation of magnetic tape throughout the Federal Government. For example, surveys have indicated costs for storing magnetic tape range from 20 cents to as high as ten dollars per reel per year among different users. In most cases these costs are no longer justified; particularly since magnetic tape has constantly changing technical characteristics.

Magnetic tape records of all types such as Computer, Instrumentation, Video and Audio recording tapes fall under the provisions of Title 44 USC, and regulations issued thereunder. Hence NARS has the broad responsibility for providing policy and procedural guidance on the maintenance, retirement, and disposition of magnetic tape records, just as it does for all other records of the Federal Government.

These recommendations provide procedural guidance to ADP installations which use magnetic tape records and particularly those which must retain records in storage for periods in excess of one year. Adherance to these recommendations will result in the following benefits:

1. Less lost time due to tape read and write errors in regular operations. Each read or write error costs approximately 5 cents in main frame time for each usage of the tape. This means that defective tape with ten or more errors will incur its replacement cost to a user through extra computer time charges in about twenty uses of the reel. Tape maintenance procedures are presented here for minimizing total operating costs.

2. Better recovery procedures when tape initially proves unreadable. Surveys of computer installations over a wide range of library sizes indicates that loss time three to ten percent due to bad tape is typical. Technical evidence shows that most users give up too soon in attempting to read bad tape and resort to expensive rerun procedures. More effective recovery procedures depending on the cause of read failure are presented here.

3. More reliable preservation of the record contents when preparing magnetic tape for off site storage. Magnetic tape libraries have been growing in most installations at an annual rate of approximately fifteen percent. Just as with paper records, not all need to be kept in the library vault at high cost. In many cases, libraries have run out of room and installations have resorted to using unsuitable storage space for magnetic tape records. This has resulted in excessive costs when the tapes are used later and the user finds that much of the data is either unreadable or readable only with excessive error rates. The cost of proper tape preparation and storage is minimal compared to the cost of recovery of that information. In general, optimal preparation and storage costs $1.77 a reel while recovery costs range from $10 to $50 a reel in most instances.

In preparing this handbook, an extensive literature search, consultation with magnetic tape manufacturers, engineers and experts, and visits to over two hundred computer installations were performed. The guidelines in this handbook are a consensus of all this experience. They have proven effective and economical in practice at a variety of installations.

1. PURPOSE AND SCOPE

These guidelines describe the optimal recommended physical, environmental, and electronic standards for users of magnetic tape. They furnish procedural guidelines for ADP installations in the handling of tape in the computer room environment, preparation of tapes for shipment and storage, optimum maintenance of a magnetic tape library, and data recovery procedures.

2. APPLICABILITY

These guidelines are recommended to all Federal agencies which record or originate magnetic tape data records as defined in 44 USC, 3301 and regulations issued under that act, and which either store such records at Federal records centers or offer such records for accessioning by the National Archives of the United States.

Procedures contained herein will be followed by the National Archives and Records Service (NARS) when tapes are accessioned by the National Archives of the United States.

3. ENVIRONMENTAL CONDITIONS FOR TAPE STORAGE ROOMS AND BUILDINGS

This section provides current recommendations for environmental conditions of tape storage facilities both in active and inactive data storage areas. The effects of failing to meet these requirements are discussed in Section 7, below.

3.1 Tape storage vaults and rooms shall be temperature and humidity controlled. A positive internal air pressure is desirable to prevent any dust intrusion.

3.1.1 Temperature range shall be 65° - $75^{\circ} \pm 5^{\circ}$ (vaults), 60° - 80° F $\pm 10^{\circ}$ F (in computer rooms). Wet bulb temperature shall not exceed 80° F.

3.1.2 Humidity range shall be 45% - 55% relative humidity, (R.H.) $\pm$ 5%.

3.1.3 Dust and dirt controls shall keep dust particles to 50 microns.

3.2 Areas used to store or condition magnetic tape should have in operation continuous temperature and humidity recording equipment.

3.3 Magnetic tape, particularly analog recordings of all kinds should be protected from high intensity magnetic or electrical fields. These include power generation facilities and transmission lines, radar installations, bulk degaussers, and magnetic check sorters.

3.4 Metal tape storage racks should be electrically grounded and at least a 2-foot separation should be maintained between all electrical fixtures and power lines and the storage racks.

3.5 Tape racks must be strong enough to safely bear the high weight of the boxes of magnetic tapes.

3.6 Tapes must be stored in an upright position, not flat on their sides.

3.7 For any storage in excess of 1 year, plastic cannisters which support the reel at the hub are strongly recommended. These provide an additional level of protection against dust, handling, environmental changes and water and smoke effects when automatic fire extinguishing equipment is triggered.

3.8 Buildings housing tape should be protected by lightning arrestors.

3.9 Magnetic tapes containing classified data must be retained in security areas meeting the appropriate agency record protection requirements regarding access.

3.10 Fire protection requirements for computer rooms, storage buildings and vaults used to house magnetic tape are described in Section 9 of these guidelines.

4. PREPARATION OF MAGNETIC TAPES FOR LONG TERM STORAGE AND SHIPMENT

The following procedures should be followed when it is known that a reel of magnetic tape will be stored in excess of one year. For shorter periods, it is assumed that backup copies, either duplicates or previous processing generations have been retained.

While it would be desirable to use most of the recommended procedures for all tapes created during normal operations, in practice the cost is too high relative to the benefits achieved for any other purpose than long-term storage.

4.1 Quality criteria of tape selected for storage.

4.1.1 Pretested and certified for usage at the storage density.

4.1.2 Certified within six months before entry into storage.

4.1.3 Maximum of five write skips allowed on the tape prior to storage entrance; none within the first 100 feet or last 200 feet.

Tapes of this quality are normally acceptable for operational use until about ten write skips accumulate. At that time, they may be cleaned and tested or sent out to be rehabilitated.

4.1.4 Previous tape life: less than fifty but more than four full length tape passes.

Like many other devices, magnetic tape also needs a "break-in" period to eliminate slight imperfections in the manufacturing process.

4.2 Processing before storage techniques.

4.2.1 Verify that an error free tape has been written by a read only pass.

4.2.2 Rewind the tape under constant tension.

Note: For full reel recordings to the EOT marker, a backward read will suffice for both verification and constant tension rewinding. However, this is possible only with nine-track tapes. For seven-track tapes, use either a tape cleaner rewinder or precision magnetic tape rewinder with constant low tension wind of between 6-8 ounces force.

4.2.3 Fasten leader securely with either vinyl or sponge rubber strips or both to prevent unwinding of the tape pack. (Note: vinyl must not be stretched).

4.2.4 Remove write enable ring from tape after dismounting from the drive that wrote the file.

4.2.5 Use self-adhesive labels with minimum residue to label tape. Write labels with any indelible medium. DO NOT USE water soluble felt tip pens or graphite pencils.

4.3 Storage container recommendations.

4.3.1 Container should be nonmagnetic and transparent so that labels can be read without opening.

4.3.2 Container should be thoroughly cleaned, dustproof, and they should have a positive action latch mechanism. Tape must be supported at the hub and not the rim.

Most cannisters on the market meet these requirements. No seal ring type devices meet these criteria.

4.4 Shipping container requirements.

4.4.1 Designed to resist heat, ingress of moisture and dirt and to withstand shock.

4.4.2 Tape reel proper should be no less than three inches from outside of case.

This will guarantee protection against even strong magnetic fields. Other techniques are (1) lining the inside of the transport case with foil or (2) using special anti-magnetic containers. The latter procedures are recommended primarily for analog tape recordings.

5. RECEIVING AND ACCEPTANCE PROCEDURES FOR MAGNETIC TAPE RECORDS

This section describes the recommended procedures to be followed upon receipt of a shipment of magnetic tape records for storage and subsequent reading.

Initial action upon receipt.

5.1 Remove tapes from packing box and check reel numbers against packing list to verify shipment.

5.2 Place reels of tape in either the storage or computer room environment for a minimum of 24 hours. This allows the tape to come into equilibrium with its new environment. If no visible damage is noted, the tapes may now be used in the local installation.

5.3 Tapes may be subject to various environmental extremes in shipment. Aircraft baggage holds may be subject to temperatures of minus 60° F. Loading dock surfaces in bright sunshine may be over 150° F. These environmental extremes may occasionally damage tape in long distance shipments. If damage or reading trouble occurs, see Section 6.4 for recovery procedures, particularly if a replacement reel cannot be readily obtained.

5.4 If tapes are to be put in storage, check reading and constant tension rewinding are recommended only if shipment was for a long distance. For short (less than 2-day transit times) distance shipments, reels may be transferred to storage area immediately.

5.5 Documentation - The shipment of recorded magnetic tapes implies an interchange of information. Two types of information are required for proper interpretation of the records. These are (1) Technical information regarding density, character code, parity, operating system labels, etc. (GSA Form 7091 may be used to record this information) and (2) Record layouts, location of control totals, the meaning of coded data elements, etc. A variety of forms and documents may accompany the records. In general, the exact content of this documentation should be agreed upon between the sender and recipient. Federal Information Processing Standard (FIPS) Publication 20 contains guidelines for describing information interchange formats. It is available from the Government Printing Office under catalog number C 13.52.20.

6. STORAGE PERIODS, MAINTENANCE AND RECOVERY PROCEDURES

6.1 Shelf Life - Magnetic tape is not now considered an archival medium. While improvements in both the medium and devices for reading tape have been substantial and frequent over the years, the great majority of computer users have at least some tapes over five years old. Studies conducted by NARS show that approximately 20 percent of a given population of tape is scrapped each year. This is primarily due to operating problems such as dropped reels, defect accumulation with usage due to stretching of the tape and dust or oxide becomming embedded in the medium, etc. Additional scrapping of tape is due to technological obsolescence. Most tape certified for 556 BPI and seven track recording has not proved suitable for nine track 3,200 FCI recording.

In addition, there are actual effects of deterioration in storage due to time alone even when magnetic tape is stored in optimal environments. For these reasons, the present shelf life of magnetic tape is estimated at about twelve years. Magnetic tapes being produced in 1971 (particularly the premium tapes) appear to have a shelf life which may approach twenty years.

All studies of magnetic tape stored for extended periods of time show that errors, both temporary and permanent, tend to increase with time in storage. The buildup rate of errors in storage is approximately an exponential function. That is, tape errors double with each year in storage. These error rates start at less than one temporary error per reel in the first year for tapes manufactured prior to 1967 to less than one error per four reels in current production tapes.

The mechanism by which magnetic tape deteriorates in storage is as follows:

(1) Minor defects become permanent errors due to plastic cold flow from nonuniform and excessive stress build-up in the tape when the tape is subjected to changes in temperature and humidity. These defects are commonly referred to as lipped edges, hard bands and defect embossments (dimples).

(2) Different rates of expansion in the length and thickness directions of the tape due to temperature and humidity changes produce stresses which permanently deform the tape. These defects are commonly referred to as cinching or windowing.

Experimental evidence shows that current production magnetic tapes are less sensitive to these environmental changes than earlier tapes. Proper periodic maintenance of magnetic tape in storage will keep the development of errors on magnetic tape recordings down to a negligible level and detect trouble in time to recover all of the recorded information. The following subsection describes these procedures:

6.2 Periodic Rewinding and Physical Inspection - The buildup of errors can be largely eliminated as long as the medium has not deteriorated. This is accomplished by periodic rewinding under constant or programmed tension. Precision winders are manufactured by several manufacturers which will unwind and rewind a 10-1/2 inch reel in approximately five minutes. This operation will redistribute the stresses in the tape and tend to eliminate some imperfections that have been formed during storage. The recommended period between such operations is one year. At the same time, any physical deterioration can be noted by the operator and further testing of suspect tapes initiated. See Section 6.4 for criteria to be used in visual inspection of magnetic tapes.

6.3 Periodic Test Reading of Sample Tapes from Inventory of Stored Files - Magnetic tapes do not fail suddenly. Rather, deterioration is noticed by a gradual accumulation of read errors both of the temporary and permanent type. Therefore, annual read checks of a sample of tape records is sufficient to spot deterioration of recordings and to allow for corrective action and recopying to occur.

At least one tape from every file should be test read on an annual basis. This should be done prior to annual rewinding. If the reel proves to have more than temporary read errors, the entire file should be test read and, if necessary, recopied on a reel for reel basis for any reel which shows permanent read errors. Temporary errors on a reel can be usually eliminated by a cleaning and rewinding operation. Such reels can then be check read again to see if the errors are eliminated. If they have been eliminated, the tape can be passed and returned to the inventory. If not, data recovery procedures may be instituted as described in Section 6.4 for recreating a new copy.

If a tape has even one permanent read error (i.e. the tape drive hangs up on a particular block, data recovery procedures should be immediately instituted and a new copy created.

For very large files, no more than a five percent sample of the reels need be test read. This five percent recommendation should also be followed in such cases where files are cumulative and augmented periodically. Examples would be any data recording activity which generates in excess of twenty reels annually. The entire series of tapes for a given year can be treated as one file for inspection purposes.

6.4 Visual Inspection Criteria - Causes and Recovery Procedures - This section describes the types of conditions which can definately generate unrecoverable read errors in a subsequent operation. Some of these conditions can be seen while the tape is being pulled out from its cannister while others can be seen only when the tape is mounted and has hung up during a read operation

6.4.1 Defects visible while tape is removed from cannister but has not been mounted on a tape drvie -

6.4.1.1 Poor wind - This is manifested in two ways. Cinching is a separation of adjacent layers of tape in the wrap with a corresponding crosswise wrinkle in the tape. This condition will lead to errors in the section of tape around the defect. It is most common in files shorter than a full reel. This trouble is also located mostly near the end of the file. In full reel recordings, the condition is caused by excessive temperature and humidity variation during shipment.

The second visible symptom of a poor wind is protruding layers of tape from the pack. This will cause edge damage and is more severe in nine track than seven track recordings. The tape pack should also be equidistant between the reel flanges. If it is not, there is a strong possibility that the reel was mishandled in shipment such as dropping or left lying on its side in a high vibration shipping mode.

Both of these symptoms, if seen, require an immediate pass of the file on a cleaner rewinder followed by a day in dead storage for stress relief and a subsequent rewind pass. After the second rewind pass, the reel may be check read to see if any data loss occurs.

6.4.1.2 Broken flange, hub, or cannister - All are indications of excessively rough handling and shipping or shelving operations. If the reel is broken, the tape pack should be immediately transferred to a new reel before any testing and recovery procedures are attempted. After the file is mounted on a new reel, perform the corrective procedures of 6.4.1.1, above.

6.4.1.3 Color changes or spots in the tape pack as seen from the side - This is almost invariably a sign of a chemical reaction between the oxide binder and whatever may have been packed with the reel. Chemicals may be in any of the following items: adhesive on labels, inks, felt tip pens, paper and the rubber or vinyl stoppers which hold the tape leader down.
At one time or another, almost all of these substances have been known to generate gases which have reacted with the binder composition and resulted in oxide pull-out. No recovery procedures can salvage data lost in this manner. The only recourse is to recreate the tape from backup copies. For this reason, the only extraneous items which should be packed with a tape reel in a cannister are new stoppers and self adhesive labels designed specifically for computer tapes.

6.4.2 Defects visible at point where tape proves unreadable - Causes and Recovery Procedures - Some visible defects are curable to the extent that a good copy of a file may be made. Others by their vary nature indicate a total loss of recording at the point of trouble. Under

These conditions, if only one or a few blocks of data are lost, some file or record reconstruction may be possible by printing the defective block(s) out and determining if any significant data was lost. Reconstructing lost records at best is a tedious job and should only be attempted if for some reason no backup file exists.

6.4.2.1 Oxide pull-out - No recovery possible. The visual symptom is a spot on the tape with missing binder which may have been transferred to an adjacent layer of tape. Clean the tape drive after removing the reel.

6.4.2.2 Surface contamination and dimples - Dirt wrapped into a reel will usually create dimples over time in adjacent layers of tape. Remove the tape from the tape drive and exercise it by two to five cleaning passes followed by a one-day stress relief storage period. Following this period exercise the tape for up to twenty passes on the drive which is to read it.

6.4.2.3 Creases and scratches - Use same procedure as in 6.4.2.2, above. Creases are usually caused by poor wrap in the tape pack. These are aggravated by poor handling and environmental conditions.

6.4.2.4 Embossments in tape wrap - Under high pressure generated by both high temperature and humidity and cycling, the end-of tape marker can generate embossments and irregularities in the last few wraps of tape in a reel. To recover data, use procedure specified in 6.4.2.2, above.

6.4.2.5 Torn tape in middle of pack - This is a sure sign that the tape has been subject to temperature and humidity extremes either in storage or transit. The block of data at that point is lost and only record reconstruction can be instituted after splicing temporarily and using the procedures of 6.4.2.2 to salvage the rest of the tape.

6.4.2.6 Adhesion and blocking - Adhesion of adjacent tape layers is due to static buildup on tape surfaces and storage of tapes in extremely dry conditions. Low humidity conditions in much office space and computer rooms is due to not procuring humidifiers in conjunction with air conditioning equipment. Recent designs of both tape drives and tapes have greatly reduced this phenomenom, but it is still occurring with tape drive designs of most second generation computing equipment and with magnetic tapes procured prior to 1967-8.

Blocking has no recovery procedure. Excessive humidity and temperature will cause the inner half inch of a tape pack to become a solid mass of mylar and binder. It can only be prevented by proper environmental conditions.

6.4.3 Unreadable or excessive error rate on tape with no visible defects - There are two possible causes of this. One is the presence of strong magnetic fields in the tape storage environment. The two primary sources of magnetic fields strong enough to affect recorded tape are magnetic ink check sorters and tape degaussers.

Magnetic ink check sorters have very powerful magnets used to extract staples and paper clips from checks entering the sorting mechanism. These can damage recordings on tapes brought to within six inches of the magnet. Magnetic tape bulk degaussers are designed to generate very large external magnetic fields to erase tape and will damage recordings within a distance of six inches. No other magnetic fields commonly found anywhere are strong enough to damage magnetic tape recordings.

The same symptoms are manifest when a tape has become skewed. That is, there is some curvature in the tape which results in misaligned bits in particular frames while the tape is under the read head of the drive.

Differentiating between these two causes requires the aid of a field engineer servicing the equipment. Oscilliscopes can determine whether the trouble is due to either reduced amplitude of the recording or misaligned bits. Once the cause of the reading trouble has been determined the recovery procedure is different in each case.

Data recovery on partially erased reels requires an adjustment of the tape drive electronics. In general, only the local field engineer can perform this adjustment.

Read trouble with skewed tapes is most prevalent at 800 BPI recording densities. The recovery procedures are the same as those given for the visible defects in Section 6.4.2; namely, several cleaning passes, each followed by a stress relief period of one day and up to twenty passes of the tape on the drive which is to read it. These operations tend to straighten out the tape.

6.5 Other recovery procedures - Some tape drives have the capability of reading backwards. If this is so, it is frequently possible to read data more reliably in this mode than in the forward direction. It has also been observed that tape which may be unreadable on one type of drive may read perfectly on another type or model. For example, the dynamic stress on tape differs considerably depending on the acceleration and speed of the drive mechanism. Recordings that marginally meet specification limits may not be readable on another drive which is itself marginal in adjustment. If repeated exercising of the tape gives unreliable reading of the file, it is possible to adjust the drive to read a particular recorded tape.

In general, only the field engineer can diagnose these conditions and make the necessary adjustment. It is obvious that these procedures are costly and should be undertaken only if the data recovery costs are less than recreating the file from backup copies.

7. EFFECT OF POOR ENVIRONMENTAL CONDITIONS ON MAGNETIC TAPE AND RECORDINGS

Most tape manufacturer recommendations for storing magnetic tape cite a temperature range of between 60 to 90 degrees Fahrenheit and a humidity range of between 20 and 80 percent. Typical published tolerances are plus or minus ten degrees on temperature and plus or minus ten percent on humidity. These environmental conditions are similar to those specified for the computers themselves.

Experimental evidence shows that the environmental conditions listed below usually cause tape reading trouble in a matter of weeks.

7.1. Temperature and humidity cycling in warehouse-grade space - Magnetic tape has a relatively high coefficient of expansion with respect to both temperature and humidity. This means that very large stresses are built up in the tape pack when it is subjected to temperature and humidity changes. This is true even though the actual temperature and humidity values may be within the limits specified for the tape. Typical conditions almost guaranteed to cause trouble are cycling between 55 and 95 degrees Fahrenheit during a six-month storage period or between fifty and ten percent humidity. A warehouse may have temperature controls but does not usually have provision for adding humidity in the winter. Under these conditions, tape will shrink. This shrinking causes increased pressure inside the pack and tends to set dimples in the tape in layers adjacent to imbedded dirt. The result on subsequent read attempts is individual frame parity errors.

Two other effects of such cycling are a result of storing tapes removed directly from tape drives. If the recording is less than a full reel, there is a winding tension difference between adjacent layers of tape at the end of the last recording made. The environmental cycling causes a shift of the entire pack at this point generating wrinkled tape near the end of the file. This phenomenum is known as cinching. The unfortunate effect of this condition is that the trouble does not manifest itself until near the end of the program subsequently using the file.

The second effect of cycling is on tapes with protruding layers of tape in the middle of the pack. Nine track tapes are particularly sensitive to edge damage from handling but in addition, these changes in environmental conditions cause unequal compression of these layers. This results in such defects as tape creases and lipped edges. In general, several feet of tape can be damaged this way making recovery of information very difficult.

7.2 Excessive temperature and humidity - This combination of conditions occurs in non-air-conditioned space. The effect is to cause blocking

of the tape and layer to layer adhesion. The newest tapes are less sensitive to these conditions than older tapes, particularly those purchased prior to 1967. The effect on a subsequent read attempt is for the tape to tear about halfway through the reel. This occurs because the layers of tape adhere with more force than the vacuum columns on typical tape drives can generate. This occurs both in warehouses in winter and some computer rooms without proper environmental controls.

7.3 Very dry conditions - This causes adhesion of adjacent layers of tape due to static buildup on the tape backing surface. The symptoms are the same as discussed in the immediately preceding paragraph. One additional trouble this kind of tape will generate is an attractiveness for dust. Initial read attempts may be satisfactory but a second usage of the tape will reveal parity errors of a temporary kind. The tape may read successfully but only at the expense of excessive reread attempts.

7.4 Effect of time - Since magnetic tape is a plastic, it exhibits the phenomenum of cold flow over time. Magnetic tape taken directly from a computer tape drive will have various unequal stress and strains wound into it while on the drive. In storage, these will tend to equalize themselves by stretching of the tape in unequal amounts. These changes are reversible up to a point and can be virtually eliminated with periodic rewinding at one-year intervals. If this is not done, the most characteristic defect will be a curvature in the tape leading to misalignment of the tape when going under the read heads or actual skew (misalignment of the individual recording tracks in time while under the read head). The symptoms are parity trouble occuring in bunches in the middle of the tape.

7.5 Strong magnetic fields - Tapes must be stored to avoid very close proximity to stray, highly powered magnetic fields, such as a bulk degausser which produces a highly concentrated field of 1500 oersteds. Laboratory tests have been conducted to determine what would constitute adequate protection. It was found that field strengths of more than 1500 oersteds would not be encountered in ordinary storage or shipping situations. Magnetic field intensity decreases rapidly with distance from the source. It was found that the degree of erasure at a distance of (3) three inches was almost immeasurable and that a 1500 oersted 60 cycle electro-magnetic source is reduced to the 50 oersted point. To obtain this data the magnetic tape was first exposed to an electro-magnetic field at varying distances and erasing effects measured. It was found that it was extremely hard to obtain any meaningful measurements at more than (3) three inches from the magnetic source. All tests have indicated that magnetic field strengths within the tape of 50 oersteds or less cause no measurable erasure and the conclusion was reached that there is a very high probability that magnetic tape is unaffected by stray magnetic fields. To obtain accidental erasure protection during shipment or during storage of magnetic tapes, simple physical spacing, of 3 inches or more from any electro-magnetic source is the easiest and least costly method suggested.

8. EFFECTS OF RECORDING DENSITIES AND MANUFACTURING TECHNIQUES ON MAGNETIC TAPE

Magnetic tape drives and reels are components of a total recording system. Although their external appearances have not changed significantly since 1955, there have been, in fact, dramatic changes in the reliability and performance capabilities of this information recording technique. This section describes factors useful to magnetic tape users regarding the changes that have taken place in tape characteristics and recording techniques over the years.

8.1 Density effects - The earlier tapes were recorded at densities of 100 to 250 bits per inch using the NRZI (Non return to zero) recording technique. These densities are now obsolete and are seldom used in new equipment, although many drives exist which will read them. Troubles occurring at these densities are the result of old tapes. The problems of older tapes will be discussed in 8.2, below. With new tapes, these densities have not been a problem. Quite successful results are on record of tapes recorded in 1960 and read error free in 1970 with no more precaution than storing the tape in a computer room environment.

At 556 BPI (bits per inch) which began to be used in the late 1950's and early 1960's, no problems have been noticed after even eight to nine years if the tape used was the best available at that time. Trouble free recordings have been observed in those installations that were able to buy premium instead of standard grade computer tape. The recording technique is also the NRZI technique and recent recordings made at this density appear to be effectively readable for the life of the physical tape as long as tape drives are available to read them.

Almost all trouble reports center around 800 BPI NRZI recordings. This is true for both 7 and 9-track tapes. As explained by magnetic tape and tape drive engineers, the primary cause of reading trouble even after a few months is the fact that for the NRZI recording technique, 800 BPI represents the upper limit of the technology. The best current tapes have a dynamic skew of one microsecond at 112 inches per second reading speed. This is a significant fraction of a wave length and means that very little stretching or shifting of tape is needed to generate a good deal of reading trouble. For this reason, 800 BPI is not recommended as the density of choice for either long term storage or information interchange.

At present (1971) good results are being achieved with 1,600 BPI phase-encoded tape. In fact, better results are being achieved at 1,600 BPI even in dual density tape drives where both 800 and 1,600 BPI density recordings can be made. Sixteen hundred BPI recordings are far less sensitive to tape degradation such as skew and dirt for the following reasons:

- The tape drive read mechanism contains a skew register specifically designed to compensate for dynamic skew.

In effect, phase encoding has a potential upper density recording limit of ten thousand BPI. The net result is a more reliable recording technique and medium combination than NRZI is at present.

- This recording technique is also less susceptable to dropouts. For example, in testing and certifying magnetic tape for NRZI recording, a 50 percent loss of signal is marginal for any recorded bit. In phase encoding, an 80 percent loss of signal is marginal. This means a reduced sensitivity to dirt and other handling damage.

In summary, the optimal densities at which to store magnetic tape records are either 556 or 1,600 BPI depending upon the particular computer. On the basis of cost involved in maintaining tapes in storage, the large advantage in space that high density offers over lower densities makes it a better practive to follow.

8.2 Magentic tape quality over the years - Magnetic tape has been improved greatly in the last fifteen years. Even the lowest grades of current production computer tape is superior to the premium tapes of even eight years ago. The following paragraphs describe the changes in magnetic tape quality factors during the 1960's.

8.2.1 Oxide shed - Early tapes generated many dropouts due to shedding of particles of oxide from the surface coating. These particles were rubbed off at the read-write head and would periodically drop off in clumps and get wound into the tape wrap. Newer tapes have almost eliminated this problem by being much smoother. Current tapes have a surface roughness of one to six micro-inches compared to double that in the early 1960's. Formulation of the binder and oxide grain itself is also much better, resulting in less trouble and wear from this source.

8.2.2 Deterioration of oxide coating - Some tapes manufactured between 1962 and 1964 had fungicides in their formulation. Many of these tapes have deteriorated in storage since the fungicide was not a stable compound. The symptom here was for the entire coating to peel off in chunks. This manufacturing practice was eliminated in all post 1964 production tapes.

8.2.3 Skew and backing stability - Current premium production tapes have a dynamic skew of one microsecond at 112 inches per second tape speed. Standard tapes have a dynamic skew of 2 microseconds. Earlier tapes had much higher skew values. It is this dynamic skew specification which makes tapes interchangeable between installations or stable in storage and is a function of the quality control and process stability in manufacturing mylar backing.

8.2.4 Sensitivity to environmental changes in temperature and humidity - Cycling tests show that both temporary and permanent errors have been reduced by 75 percent between 1965 and 1968 production tapes. Even if some dirt is embedded in current tape, only one or two wrap layers will show dimpling. Also fewer cleaning and exercising passes are required to restore the surface of the tape for data recovery to take place. Additional changes in the coefficient of friction between the backing and oxide surfaces result in less defects showing up after poor environmental storage; particularly cinching and tearing.

8.2.5 Sensitivity to dryness - Tapes stored in low humidity have often generated much static electricity on the tape surface. Over the years, surface resisitance of both oxide and mylar surfaces have been reduced. The result is a bleed off of the electrostatic charges and less attraction for atmospheric dirt or adhesion of adjacent tape layers during a read operation.

9. FIRE PROTECTION

9.1 Magnetic tape, tape reels, and containers are all extremely susceptible to heat, steam, and fire and also are potential contributors to fire. Tape reels and containers should be made of fire resistant materials when possible. All rooms and areas in which tapes, reels, and containers are to be used or stored must, therefore, provide for protection against fire as one of the major considerations.

9.1.1 No open flame (matches, cigarette lighters) or smoking should be allowed in tape handling areas. Smoke particles deposited on the tape have been known to cause dropouts.

9.1.2 Tape vaults must be insulated to provide fire resistance limits up to 150° F temperature and 85% relative humidity.

9.1.3 Combustibles such as wood, paper, volatile cleaning fluids, etc., must be kept to a minimum in tape storage areas.

9.1.4 The use of CO_2 (Carbon Dioxide) extinguishers and H_2O (water) are recommended in fire extinguishment. The use of water requires that all tapes must be carefully dried within 24 hours to avoid "cupping and blocking."

9.1.5 Fire protection requirements shall be in accordance with "Fire Protection for Essential Electronic Equipment" (RP-1) issued by the Federal Fire Council, (1969 revision).

10. EFFECTS OF NUCLEAR RADIATION

10.1 Physical Effects

Studies have indicated that the effects of gamma and/or beta dosage on the physical and magnetic properties of magnetic tape causes little or no physical damage up to the 50-megarep level. Above the 50-megarep level Polyester base materials begin to show some physical deterioration. The tape backing and coating will show significant embrittlement (easily broken, cracked or snapped) and life of the tape could be reduced by as much as 60%.

10.2 Magnetic Properties

It has been determined that magnetic tape will be unaffected by nuclear radiation until the dosage approaches a level at least 100 megareps (Note: Megarep equals 1 million roentgen equivalent physical). Radiation of the magnitude would only increase the layer-to-layer "print-through" by approximately 4 db. This print-through effect is so slight that it is not considered serious, and would not prevent retrieval of the information stored on the tape.

This amount of radiation, 100 megarep, will also have some effects on the tape coating. The effect of Neutron bombardment on the coating (iron-oxide and binder) would no doubt be limited to activation of the iron-oxide coating, which would produce a radioactive isotope that itself might become another source of radiation. It is theorized that such activation would not produce a change in the overall magnetic properties of the coating.

11. HANDLING TAPE IN ACTIVE AREAS

11.1 Tapes should not be touched with the fingers, (the use of lint-free gloves is recommended where an unusual amount of handling occurs).

11.2 Working areas should be devoid of all substances that can adhere to the tape causing dust and lint to collect. Among those substances are such common items as cigarette ashes, food, drinks, floor and other types of waxes.

11.2.1 No eating or smoking in computer or tape storage areas. Food particles can be just as harmful as smoke particles.

11.3 Tapes should be handled in a careful manner, not pulled, yanked, squeezed, or scratched, and they should be protected against heat changes and fire hazard during all transportation operations.

11.4 Tapes, reels or containers should not be thrown or dropped, when either empty or full.

11.4.1 Replace any old or damaged reels and inspect all take-up reels on tape drives weekly.

11.5 The following page contains a check list for magnetic tape users and custodians. It is a summary of critical factors involved in the long term preservation of magnetic tapes.

SUGGESTED CHECK LIST

Active Tape Area

1. Fire proof building ___
2. CO_2 extinguishers ___
3. No open flames ___
4. No smoking ___
5. Dust free conditions ___
6. No paper chips (keypunch and printers) ___
7. No food ___
8. No waxed floors ___
9. Temp. 70^{o} F $\pm$ 5^{o} ___
10. Humidity 50% $\pm$ 5^{o} ___
11. No magnetic fields ___
12. Positive internal air pressure ___

Storage Cabinets or Racks

1. Shelves adequate in strength ___
2. Dust free conditions ___
3. 2' clearance to any electrical fixture ___
4. Electrically grounded ___
5. Vertical stacking of tape ___
6. No magnetic door latches ___

Tape Containers

1. Cleaned between use ___
2. Hub supported ___
3. Dust tight ___

Inactive Storage Areas

1. Fire proof and protected ___
2. No fire hazards ___
3. Dust free conditions ___
4. Temp. 70^{o} F $\pm$ 5^{o} ___
5. Humidity 50% $\pm$ 5^{o} ___
6. No close magnetic fields ___
7. Positive internal air pressure ___

In Transit - short time period

1. Fire resistant packaging ___
2. Dust protected ___
3. Careful handling ___
4. No bumping ___
5. Temp. 50-90^{o} F $\pm$ 10^{o} ___
6. Humidity 40-60% $\pm$ 10% ___
7. Inspected before and after shipment ___

Tape Handling

1. No finger contact ___
2. Lint free gloves ___
3. Careful handling ___
4. Clean transports every shift ___
5. "Low-wind tension" ___
6. Rewound annually ___
7. Certified product ___
8. Receiving inspection ___

Tape Reels

1. No sharp edges ___
2. Undistorted flanges and hub ___
3. Labeled properly ___